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ANNOUNCEMENT OF ANNUAL MEETING

The Annual Meeting of the Potato Association of America will be held in conjunction with the American Phytopathological Society at Estes Park Conference Camp, Estes Park, Colorado, August 24-28, 1954.

1. LODGING ACCOMMODATIONS:

(a) Lodges and Sleeping Cabins — Rooms for 2 or 4 persons each. For families without children or with 2 small children and individuals who can room together. Indicate any preference for a room mate. No cooking facilities.

(b) Cabins for Families — For families with 2 or more children including families of 4 or more if one child is 11 or older. Cooking facilities in some cabins, however regular conference rate required from head of family plus a slight charge for other family members.

2. DINING ROOM ACCOMMODATIONS:

Three dining rooms available so that all guests may eat at one time.

3. SERVICE — Maid service, towels and all bedding furnished. A hostess shall be in charge of the lodges. Experienced hikemasters, naturalists, guides, horsemen, *etc.*, will be available.

4. RESERVATIONS —

(a) Families (man, wife and children) deadline June 30, 1954. Families with 2 or more children should indicate desire for cabin with cooking facilities if required.

(b) All others must make reservations by July 31.

Send all reservations to Dr. R. H. Porter, Botany and Plant Pathology Department, Colorado A & M College, Fort Collins, Colorado.

5. RATES —

(a) Conference Rates (includes lodging and meals). For adults (12 years and over) $25.00 each; for children (7 to 11 yrs.) $21.00 each; (2 to 6 yrs.) $18.00 each.

(b) Daily Rates (includes lodging and meals). For adults (12 yrs. and over) $6.50; children (7 to 11 yrs) $5.50 each; (2 to 6 yrs.) $4.75 each. All persons attending the meetings of the Phytopathological Society and the American Potato Association, and staying at the Camp will be expected to pay according to the conference rates as listed. Members of families who wish may also pay regular conference rates. Members of families who wish to prepare their own meals may do so, but will be charged a reasonable fee for lodging. In addition, they will pay for the Chuck Wagon dinner if they wish to attend.

(c) The Chuck Wagon Dinner, Wednesday night included in Conference rate. An extra charge will be made for persons who do their own cooking. Their desire to attend this dinner should be noted in reservation request. This will replace the usual banquet.

6. TRANSPORTATION — Purchase railroad and bus tickets to Estes Park; Air line tickets to Denver. The Rocky Mountain Transportation bus serves Estes Park and the Conference Camp.

7. **ENTERTAINMENT** — On Friday afternoon, August 27, arrangements shall be made for a sight-seeing tour into the mountains. We will go to Bear Lake, and up Trail Ridge road (paved) above timberline, to the top-of-the-world at the Continental Divide. This trip, alone, is well worth coming to Colorado to see. Besides the scheduled sight-seeing tour, the following activities will be available for members of families who do not wish to attend the meetings: (1) Hikes over mountain trails led by experienced hikemasters and naturalists. (2) Saddle livery with mountain-trained horses and ponies for children and inexperienced riders, and cowpokes and cowgals. (3) Fishing for trout in a mountain stream is a sport one should not pass up. A visitor's license for three or ten days can be purchased. There are two trout streams close by the camp. (4) Square dancing for all ages. (5) There are a playground and kindergarten cabin for children from 3 to 6 years of age, under experienced kindergarten instructors. (6) Archery, hobby grounds, tennis, riflery, and picnics for teen-agers. (7) Golf privileges, for a reasonable green fee, can be had at the Estes Park Country Club. Check the bulletin board in the Administration Building for scheduled party trips which you can join.

8. **WEATHER** — Normally the days are pleasantly cool, and a typical afternoon mountain shower may last for a few minutes and be over. Estes Park Conference Camp is at an altitude of approximately 8,000 feet, and the nights are always quite cool. Therefore, *bring along a rain coat and a top coat* regardless of how hot the weather is where you live.

9. **CALL FOR PAPERS** — Titles and abstracts of papers for presentation at the meetings of the Potato Association of America should be sent to Cecil Frutchey, Colorado A & M College, Fort Collins, Colorado, by June 24. A joint session with the American Phytopathological Society is planned. Please indicate length of time required for presentation and your need for projectors, *etc.*

RESERVATION — ESTES PARK MEETING

POTATO ASSOCIATION OF AMERICA

AUGUST 25-26-27, 1954

Name ....

Address ....

Number in Party ....

Include Ages of Children ....

Date of Arrival ....

Method of Travel ....

Number Attending Chuck Wagon Dinner ....

Send to **Dr. R. H. Porter, Dept. Plant Pathology, Colorado A & M College, Ft. Collins, Colorado**

ASTER YELLOWS (PURPLE-TOP) OF POTATOES[1]

D. J. MACLEOD

Purple-top is an important limiting factor in potato production in certain sections of Canada, Mexico and the United States. Most of the cultivated varieties are susceptible to this disease.

One of the earliest references to this disease is that of Muncie (28) who published in 1931 a description of a disease known as "moron" previously recorded by J. W. Weston in Michigan in 1915.

Folsom (7), was probably dealing with the same disease when he differentiated "yellow-top" from other non-mosaic virus diseases of Green Mountain in Maine in 1925. Folsom (8) also published a full account of the yellow-top disease, and concluded that it is probably identical with one or more of a group of similar diseases; namely, aster yellows, purple-top, witches broom and apical leafroll.

Orton and Hill (29) reported that the disease has been prevalent in West Virginia since 1931 and published a complete description of the general symptoms in the Rural variety under the name of "blue stem". They also gave an account of comparative histological and microchemical studies of non-infected and infected potato plants and tubers and emphasized certain internal microscopic symptoms as being of some diagnostic value. These included the brownish cortical and vascular necrosis involving the the lower region of the stem, the stolons and roots and the dendritic necrosis in the stolon end of the tuber suggestive of net necrosis.

Severin and Haasis (34) produced symptoms resembling purple-top in Bliss Triumph and White Rose potatoes when the California aster yellow virus was transmitted to these plants by means of the six-spotted leafhopper *Macrosteles divisus* (Uhl). Severin (33) also found a volunteer potato plant with sessile aerial tubers and purple leaves from which he was able to recover the aster yellows virus by means of a physiological race of *Macrosteles divisus*.

Sanford and Clay (30) described a disease resembling purple-top wilt affecting Netted Gem in Alberta which they designated as "purple dwarf". They transferred the disease to healthy potato by grafting and established its virus origin. Their observations also indicated that the disease was transmitted through the tubers.

Epps (16) produced purple-top wilt symptoms in potato when the New York aster yellows virus was transferred to this host from aster by means of *Macrosteles divisus*. He succeeded also in transmitting the aster yellows virus to aster from *Nicotiana rustica* L. plants on which scions from purple-top infected potato plants had been grafted.

Younkin (37) produced further evidence for the implication of the new York aster yellows virus in the causation of purple-top wilt in potato. In

[1]Accepted for publication November 2, 1953.
An invitational paper presented at the Symposium on Potato Virus Diseases at the 40th Annual Meeting of The Potato Association of America in Madison, Wis., September 7, 1953. Contribution No. 1317 from the Botany and Plant Pathology Division, Science Service, Department of Agriculture, Ottawa, Canada.

[2]Pathologist-in-Charge, Laboratory of Plant Pathology, Fredericton, New Brunswick, Canada.

extensive tests, he showed that purple-top symptoms were induced in potato to which a source of aster yellows from naturally infected *Ambrosia artemisifolia* L. was conveyed by *Macrosteles divisus.*

Beall and Cannon (2) made a statistical study of the distribution of purple-top within tuber unit plantings in Prince Edward Island. They demonstrated that the cause may operate variously over a field but with similar freedom along and across the rows, but does not appear to be transmitted from a plant to its neighbor. There were some indications that a regular proportion of plants in each tuber unit tended to acquire the disease indicating that the mother tuber for each unit was involved.

Leach and Bishop (15) published a detailed account of the purple-top disease as occurring in the Green Mountain, Bliss Triumph and Rural varieties in Minnesota. They also presented evidence to show that the disease dealt with is caused by the aster yellows virus, and transmitted it from infected asters to potato by means of *Macrosteles divisus.* Leach and Bishop were unable to transmit the virus from purple-top affected potatoes to aster or potato by means of the species of leafhopper used. They also stated that infection apparently does not spread from potato to potato but probably arises from migratory infected adult leafhoppers.

Jensen and Tate (11) and Self (32) produce further evidence supporting the conclusion that purple-top wilt is induced by the aster yellows virus and is transmitted by *Macrosteles divisus.*

Kunkel (13) was unable in numerous trials to transmit the New York aster yellows virus means of *Macrosteles divisus* to the following varieties of potatoes: Irish Cobbler, Green Mountain, Bliss Triumph and Spaulding Rose. Kunkel (14) also examined certain Green Mountain plants affected with yellow-top from Maine and concluded that this disease was not caused by the aster yellows virus. He succeeded in transmitting the virus involved by means of dodder *Cuscuta campestris* Yunker, to potato, tomato and other hosts.

MacLeod (17), (18), (20), (23), made a study of a disease similar to purple-top called bunch-top, in New Brunswick.

He described the disease as occurring in the Katahdin, (Figure 1), Green Mountain and Sebago varieties and transmitted the virus causing the disease in these hosts by stem grafting to potato (Katahdin and Green Mountain), *Datura stramonium* L., *Lycium halimifolium* Mill., *Lycopersicum esculentum* Mill. (Bonny Best), *Nicotiana glutinosa* L., *Nicotiana rustica* L., *Nicotiana tabacum* L., (Samsun), *Petunia hybrida* Vilm., and *Physalis Alkekengi* L. All attempts to transmit the virus by stem grafting to *Capsicum annuum* L., *Solanum dulcamara* L., and *Solanum nigrum* L. var., *nudiflorum* were unsuccessful. The virus was also transmitted from affected potato (Katahdin and Green Mountain) to the hosts enumerated above excepting *Petunia hybrida* and *Physalis Alkekengi* by means of *Cuscuta gronovii* Wild. Purple-top symptoms were also produced in potato (Katahdin and Green Mountain) and *Lycopersicum esculentum* (Bonny Best) with a virus transferred to these hosts by means of dodder, *Cuscuta gronovii,* from natural grown sources of *Asclepias syriaca* L., *Erigeron canadensis* L., *Datura stramonium* L., *Physalis floridana,* L., *Petunia hybrida* Vilm., *Solanum melongena* L., *Lycopersicum esculentum* and *Trifolium pratense* L. All the plants from which this source of virus was obtained showed symptoms similar to those produced by the

bunch-top virus in other susceptible hosts. A disease of virus origin resembling purple-top was also found in rutabaga *Brassica Napobrassica* Mill. (Laurentian) and wild radish *Raphanus Rhaphanistrum* L. The virus causing the disease in these hosts was transmitted by stem grafting to two varieties of rutabaga (Laurentian and Wilhelmsburger) and a source of wild radish in which the typical symptoms found in the original plants were reproduced.

MacLeod (19), (22), failed in several attempts to transmit the bunch-top virus obtained from Katahdin, Green Mountain and Sebago sources by means of *Macrosteles divisus* to other hosts including potato (Katahdin, Green Mountain and Sebago) *Callistephus chinensis,* Nees., *Datura Stramonium* L. and *Nicotiana rustica* L. He was also unable using *Macrosteles divisus* to transfer three sources of the aster yellows virus found in aster, carrot and Tartarian buckwheat to potato (Katahdin and Green Mountain) and *Lycopersicum esculentum* (Bonny Best).

The virus found associated with the bunch-top disease in New Brunswick has certain affinities with the aster yellows virus but differs in that it does not cause sterility in susceptible hosts. Furthmore, the bunch-top virus is transmissible by grafting to *Datura stramonium* and *Nicotiana tabacum,* which Kunkel (13) considers are immune to the aster yellows virus. Keener (12) also concluded that the virus causing purple-top in potato in Arizona differs from the aster yellows virus because it is transmissible by grafting to *Nicotiana tabacum* and *Nicotiana glutinosa.*

Hutton and Oldaker (10) described a disease in Tasmanian potatoes called rosette that has certain affinities with the purple-top disease. They succeeded in transmitting the virus causing this disease by grafting from potato to potato (Carman), to tomato and to tobacco. They noted also that the tuber progeny of Brownell potatoes affected with the disease all produced plants with rosette symptoms throughout two generations.

Menzies (26) studied the purple-top disease in the State of Washington and succeeded in transmitting a virus from infected potato to tomato by stem grafting and from tomato to tomato by means of dodder *Cuscuta subinclusa.* Menzies concluded from the characteristic symptoms produced by this virus in tomato that the tomato big bud virus described by Samuel, Bald and Eardley (31) in Australia may be involved. MacLeod (17) also observed certain symptoms characteristic of the tomato big bud virus in some varieties of tomatoes to which the bunch-top virus was transmitted by stem grafting. These included the enlargement of the terminal shoots and the tufted effect in aged and pruned plants resulting from extreme proliferation of the lateral shoots. It is interesting to note in this connection that when Dr. D. O. Noris of Australia was shown tomato plants infected with bunch-top virus in Fredericton, New Brunswick, he remarked that there was considerable similarity in the symptoms observed in these tomato plants and those produced in this host by the big bud virus.

McKay and Dykstra (25) and Severin (33) established that the sugar beet curly top virus is capable of producing a yellows type of disease in tomato and potato. Certain of the symptoms induced by this virus in tomato and potato (chlorosis, rolling and purpling of the leaves and dwarfing of the plant) are similar to those frequently associated with the purple-top disease in these hosts.

Milbrath (27) described a virus disease in Netted Gem bearing some affinity to purple-top which he designated as green dwarf. Menzies (26) reported that Dr. N. J. Giddings of Riverside, California examined specimens of green dwarf found in Washington and concluded that a strain of the sugar beet curly top virus was involved.

Bonde and Schultz (5) published a detailed account of the purple-top wilt disease as occurring in Katahdin, Green Mountain and Sebago in Maine. They demonstrated that the virus is transmissible from potato (Katahdin) to tomato (Marglobe) by inarch grafting but were unable to produce current season symptoms of purple-top wilt in potato (Katahdin) to which infected scions were attached. Bonde and Schultz also failed to produce typical purple-top symptoms in Katahdin and Green Mountain plants upon which *Macrosteles divisus* bearing a source of aster yellows from *Sonchus asper* L. Hill., and *Chrysanthemum leucanthemum* L. were allowed to feed. They stated also that the tubers borne on the plants infected with the aster yellows virus failed to germinate or had weak sprouts. Schultz and Bonde further investigated the apical leafroll disease described by them in 1929 (35) and established that the virus causing this disease is readily transmitted by grafting from potato (Spaulding Rose) to potato (Katahdin) and to tomato (Marglobe) and is also perpetuated in both aerial and subterranean tubers. Furthermore, they state that the symptoms produced by the apical leafroll virus are different from those induced by the purple-top virus in tomato when these viruses are transmitted to this host by inarch grafting. Bonde and Schultz also found that the apical leafroll virus is transmitted from potato to potato by means of *Macrosteles divisus*. They failed, however, in numerous atempts, to transmit this virus by means of *Macrosteles divisus* to aster.

Leach and Bishop (15) claimed that the causal agency of the purple-top disease (aster yellows virus) did not survive long in the potato plant and is not transmitted through the tubers. Self (32) recorded that the purple-top virus is only occasionally perpetuated in aerial tubers indicating that the affected plant sometimes outlives the virus. MacLeod (19), (23), found that the bunch-top virus sometimes is irregularly dispersed throughout the haulm of the plant (Figure 1) and when it enters the tuber it may infect the whole or only part of that organ. The parts of the tuber that become involved by the virus remain hard and intact for many months, whereas the unaffected portions soften and generally disintegrate. The eyes on the sections of tubers that are permeated by the virus frequently do not germinate and sometimes produce weak, spindling sprouts as shown in figure 2. These weak sprouts usually collapse in ten to fourteen days following emergence under normal field conditions. Occasionally, more vigorous sprouts emerge from the infected sections of the tubers that may develop to weak or dwarfed plants as seen in figure 3. These plants sometimes manifest symptoms resembling those associated with the "haywire" disease described by Goss (9) in Nebraska. Plants so affected generally become chlorotic, wilt and collapse in three to six weeks. Occasionally, the plants produced from infected tubers may continue to grow for several weeks and develop the characteristic bunch-top symptoms induced in the parent plant the previous season. The basal sections of these dwarfed and wilted plants frequently manifest a brownish necrosis of the vascular and cortical elements, that extend into the roots, stolons and the stem end of the tuber where a type of net-necrosis is produced. When scions

FIGURE 1.—Katahdin, showing purple-top (bunch-top) advanced symptoms.

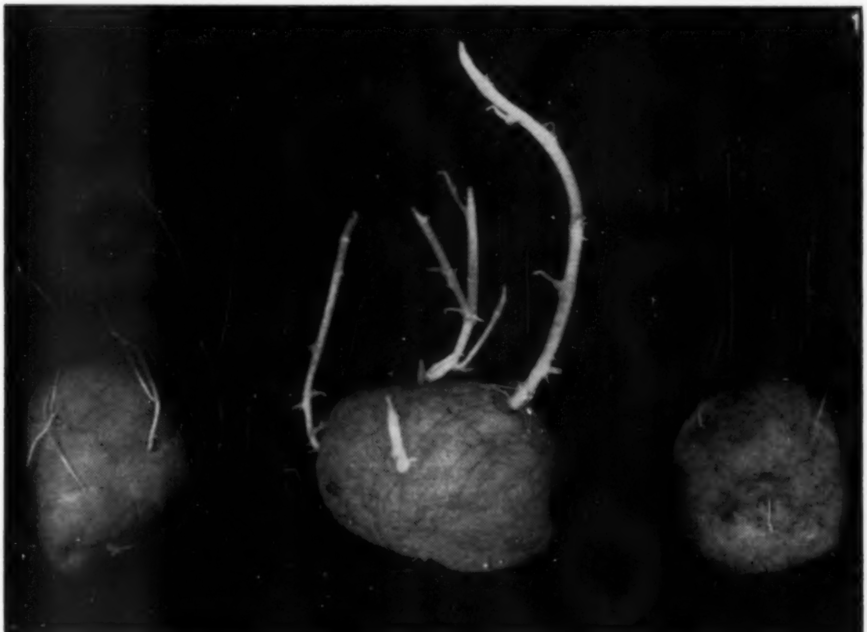

FIGURE 2.—Katahdin tubers—Right and left show spindling sprout effect associated with purple-top (bunch-top). Tuber in center from control plant.

FIGURE 3.—Katahdin showing purple-top (bunch-top) in second generation plant. This stage resembles "haywire" effect.

from second generation plants which showed bunch-top symptoms (haywire effect and dwarfing) were grafted to potato (Katahdin and Green Mountain) and tomato (Bonny Best), symptoms characteristic of the bunch-top virus were produced in these hosts. Also, when dodder *Cuscuta gronovii* was used as the mode of transmission, a virus was transferred from these infected second generation plants, that gave rise to bunch-top symptoms in tomato (Bonny Best) and *Nicotiana rustica.* This finding indicates that the virus causing bunch-top is capable of entering the potato tuber and passing into plants that are produced from these infected tubers. When scions from normal appearing plants that were produced from tubers borne on bunch-top affected plants, were grafted to potato (Katahdin and Green Mountain) and tomato (Bonny Best) no symptoms appeared in these plants. During the investigation of the transmission of the bunch-top virus, it was found that this virus was transferred from potato to potato by stem grafting with difficulty, but was passed from infected potato scions to tomato and other solanaceous hosts with greater regularity and ease. The reason for the difficulty in transmitting the virus by stem grafting from potato to potato, is possibly due to the low concentration of this virus that occurs in this host, and the condition imposed by the fact that this virus does not always become completely systemic in the potato. The bunch-top virus becomes more completely systemic in such hosts as tomato, *Nicotiana rustica* and other solanaceous hosts.

When the viruses causing bunch-top and leafroll were introduced simultaneously by stem grafting to potato (Green Mountain and Netted Gem) a syndrome was produced in the aerial portions of the plants that manifested some of the characteristic symptoms of both viruses. There was also an intensification of the dendritic necrosis (net-necrosis) occurring in the tubers borne on these plants. In addition, the areas in these tubers co-extensive with the net-necrosis condition exhibited a marked bluish-green fluorescence in ultraviolet light, caused by the presence of the compound scopoletin identified by Best (3) and Andreae (1). This compound was also found in the areas showing dendritic necrosis in the stolon end of tubers affected with the bunch-top virus alone. It may be of some interest to mention that in all these trials, the net necrosis condition was not produced in Green Mountain and Netted Gem tubers when a common strain of the leafroll virus alone was introduced to plants of these varieties by means of stem grafting or by the aphid *Myzus persicae* Sulzer.

Long (16) concluded that the condition known as "hair sprout" in potato tubers is linked with the purple-top disease. Bonde (4) later confirmed this finding and reported that tubers from plants affected with purple-top developed small secondary tubers in the soil without producing plants. Bonde and Schultz (5) record instances where from 20 to 75 per cent of the seed failed to produce normal plants because of the hair sprout condition that develops in purple-top wilt infected seed stocks. MacLeod (24) also noted a case where the bunch-top virus (carried over in the tubers) suppressed germination to the extent that 22 per cent of these infected tubers failed to produce healthy plants.

Bonde and Schultz (5), Folsom (8), Leach and Bishop (15), Menzies (26), Orton and Hill (29), and others have commented on the similarity of certain symptoms associated with the purple-top disease and those produced by the viruses that cause apical and primary leafroll and similar diseases. MacLeod (21) reported a late season effect (late leafroll) that occurred in Green Mountain, Irish Cobbler, Katahdin and Pontiac in Eastern Canada. Late leafroll is characterized by a rolling of the leaflets in the upper section of the plant and the development of a reddish or yellowish coloration in the stems and leaves, somewhat resembling apical leafroll. When scions from plants showing the late leafroll effect were grafted to tomato (Bonny Best), symptoms resembling those characteristics of the bunch-top virus were produced in all the grafted plants. It would appear from this finding that the "late leafroll" effect is the symptom expression produced in certain varieties of potatoes when the bunch-top virus enters the potato plant during its maturing stages. Noteworthy in this connection is the fact that while a large percentage of plants manifested this late season effect of the disease, none of the tubers borne on such plants became infected with the virus. This is probably due to the slow movement of this virus to the subterranean parts of the plant.

Wright (36) distinguished two strains of the witches broom virus occurring in British Columbia. One of these strains, when communicated to tomato (Bonny Best by grafting gave rise to symptoms resembling those produced by the tomato big bud virus and the purple-top virus in this host. Kunkel (14) also found a virus that he identified as witches broom in a source of Green Mountain showing yellow-top symptoms. The author also found a yellow type virus in Green Mountain plants

that were produced from tubers showing severe net-necrosis. This virus gave rise to symptoms somewhat resembling witches broom in tomato (Bonny Best) and produced a yellow-top (bunch-top) effect in Green Mountain when transmitted to these two hosts by stem grafting.

Summary

This review of some of the facts concerning the purple-top disease reveals that it has been variously described as blue stem, yellow-top, purple-top wilt., purple dwarf, and bunch-top. Certain phases of the disease have been recorded as late leafroll, apical leafroll and haywire.

The facts presented here also indicate that the purple-top disease is evidently not caused by a single entity but is the common expression given in the potato and other hosts to two or more viruses belonging to the yellows group. The purple-top effect is also producecd when certain fungi, bacteria and physical agencies injure the base of the plant and the roots. The expression of each virus involved may be modified by the intergrading of the symptoms produced by this virus with those associated with the viruses that cause leafroll, apical leafroll and witches broom, and other agencies. The symptoms of the viruses involved may also vary according to the time of the season when initial infection takes place. If the virus enters the plant early in the season the disease may pass through its primary, intermediary and secondary stages in one season. If infection occurs late in the season only the primary phase of the disease may become evident. When the primary stage of purple-top is concurrent with the maturing phase of the plant, the symptoms may assume the effect known as "late leafroll" which somewhat resembles primary and apical leafroll. These symptom complexes account for some of the variations of the purple-top disease that have been observed.

When the aster yellows virus is the causal agent of purple-top it is probably transferred to the potato from infected weeds and other plants that serve as overwintering hosts by one or more of the six leafhoppers included in the species complex now designated as *Macrosteles (Macrosteles) fascifrons* (Stal.).

Owing to the fact that the virus found associated with the bunch-top disease in Canada attacks weeds including *Asclepias syriaca* and *Erigeron canadensis* and also red clover *Trifolium pratense*, it is possible that these infected hosts may serve as reservoirs from which insects, (leafhoppers) can transmit the virus to potato plants growing in proximity to these infected sources. No vector has been found for the virus occurring in Canada.

The aster yellows virus established to be the cause of the purple-top disease in certain parts of the United States, is apparently not transmitted through the tubers. The virus found associated with the disease in Canada is capable of entering the tubers and may involve the plants produced from such tubers, but is rarely tuber borne beyond the second generation. While the virus found in Canada has certain aspects in common with the aster yellows virus, it differs from this virus in that it does not cause sterility in the hosts attacked and is readily transmitted by stem grafting to *Nicotiana tabacum* and *Datura stramonium* which are considered to be immune to the aster yellows virus. The bunch-top virus sometimes produces a dendritic necrosis (net-necrosis) in the stem end of the tuber and also spindling sprout effect in certain varieties of potatoes. The

net-necrosis effect was intensified when the bunch-top and leafroll viruses occurred simultaneously in the tuber. The leafroll virus alone failed to produce this net-necrosis symptom in certain varieties that are capable of expressing this necrotic effect.

The purple-top disease has been reported by a number of investigators to be of considerable economic importance in certain potato producing areas in Canada, Mexico and the United States. During its current season phases it lowers the vitality of the plant by interfering with the function of the vascular system. When the virus enters the tubers it suppresses the germination of the infected eyes that resulted in misses or the production of weak plants that are usually unproductive. This feature alone renders the disease of supreme importance especially in areas where conditions are conducive to the spread of the viruses involved.

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TESTING FOR LATE BLIGHT RESISTANCE IN THE POTATO IN CANADA[1]

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Twenty years have elapsed since the Canadian Potato Breeding Project was initiated as a co-operative effort between the Experimental Station, the Laboratory of Plant Pathology and the Laboratory of Agricultural Entomology at Fredericton, New Brunswick. In this project the Experimental Station assumes responsibility for the horticultural phases of the program, including the crossing, production, multiplication and horticultural assessment of the new potato productions. The Laboratory of Plant Pathology makes the determination of disease resistance while the Laboratory of Agricultural Entomology undertakes the studies concerning insect resistance. The Division of Horticulture, Central Experimental Farm, Ottawa, supervises the testing of seedlings for their horticultural suitability throughout Canada. A group consisting of certain active workers and interested individuals comprises the working committee at Fredericton, whereas a central committee composed of the heads of certain divisions or their representatives comprise the policy committee at Ottawa. An average of fifteen persons devote most of their time to the active pursuit of the work.

The objective of the program is the production of new potato varieties combining resistance to one or more plant diseases or insect pests, with suitable horticultural attributes. The major emphasis is placed upon breeding for resistance to two common diseases, late blight and common scab, but other fields of endeavor are explored including breeding for resistance to viruses X, A, Y, leafroll, ring rot, and aphids. In addition, selected seedlings are tested for their resistance to wart, Fusarium dry rot, and Verticillium wilt. Since the inception of the breeding program 235,283 seedlings have been produced of which 144,075 have been bred essentially for late blight resistance.

Breeding for resistance against *Phytophthora infestans* actually began in the year 1934 when a total of eighty-two *S. demissum* x *S. tuberosum* hybrids was produced. These seedlings were not tested until the year 1935 when all were found to be resistant to late blight.

In the first two years of the project, the testing was done in large, covered crocks, lined with water-saturated sphagnum moss. The method, however, was deemed unsuitable for various reasons and in the year 1935 a large blight chamber was constructed. This chamber was 18 feet long, 4 feet wide and some 4 feet high from the floor to the peak of the pitched roof. Aside from the superstructure it was built entirely of glass. A saturated atmosphere was maintained in the chamber by

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frequent sprayings and the maintenance of a moist layer of moss over the floor of the chamber. The chamber was housed in a section of the greenhouse where it was influenced by the changes in the surrounding atmosphere. Much trouble was experienced at first because of temperature fluctuations beyond the optimum. Later, attempts were made through shading with canvas sheets and by means of ice cakes to maintain the temperature at 70° F. or lower. This was not wholly successful but it served to reduce somewhat the loss occasioned by the development of damping-off fungi, *Botrytis* and bacterial soft rots. A further development was the attempt to cool the cage with a stream of water which flowed over the external surface of the glass from a perforated pipe running along the peak of the chamber. During this period the use of a 0.25 per cent solution of Semesan was found to be most effective in preventing pre- and post-emergence damping-off. Finally all difficulties were overcome by the installation of an automatic cooling and humidifying system in 1949.

Breeding for late blight resistance has been confined mainly to hybridizing *S. demissum*, the female parent, with desirable, mainly North American varieties of the common potato.

For a number of years the seedlings were sprayed once or twice daily with a suspension of conidia and zoospores of the fungus until a maximum of ten inoculations was made. At the present time this number has been reduced to one or two. The test organism utilized is maintained in the laboratory on potato dextrose or rye-meal agar. When used in the blight chamber, it is first cultured on slices of sterile, raw tubers and later transferred to the detached foliage of healthy Green Mountain potatoes or other commercial varieties. On occasion, however, the leaves of diseased seedlings have been utilized.

When the blight chamber was first used in 1935 it was noticed that many seedlings reacted to infection with the development of necrotic or hypersensitive spots. On the basis of their reaction, the seedlings were divided into three categories; namely, immune, resistant and susceptible.

The immune or reaction O seedlings show no visual symptoms of infection whatsoever and although microscopic examination has often failed to reveal any evidence of cellular changes, occasionally different degrees of a brownish reaction may be detected in the cells. It is thus possible to find a series of reactions gradually merging this group with the resistant or necrogenous group which can be visually determined.

The resistant group designated by the reactions 1, 2 and 3 characterizes an assemblage of decreasingly resistant plants upon which the fungus never fruits.

The susceptible category includes the reactions designated 4, $\bar{5}$ and 5.

Reaction 4 is characterized by small, atypical fruiting lesions of the fungus.

Reaction $\bar{5}$ characterizes the slight resistance to the so-called common form of the fungus manifested by such varieties as Sebago, Ekishirazu, and No Blight.

Reaction 5 includes the completely susceptible plants upon which the fungus fruits luxuriantly. There is considerable difference in the time period before susceptible varieties succumb to the same degree. In addition, the speed of this reaction may be modified by the temperature

prevailing during the test and it may be profoundly affected by the biologic form employed.

In 1936 about 5,000 *S. demissum* x *S. tuberosum* seedlings were tested as well as several hundred European and South American named varieties, the latter mostly *S. andigenum* clones. A disturbing feature of that year's tests was the appearance of several blighted plants in the F_1 crosses. This result might be attributed to heterozygosity in the *S. demissum* or female parent, but dozens of subsequent tests involving hundreds of *S. demissum* clones have failed to substantiate this condition. Conceivably a new biologic form of the fungus may have developed during these tests.

Inoculation was effected on plants about 3 inches high and they were left in the cage for a period of 14 days during which they tended to become leggy. This practice was discontinued in 1939 because the etiolated condition of the plants made them most difficult to handle.

In 1939 the program was modified to retain the seedlings included in reactions 4 and 5 and experience indicated that all seedlings in the third or subsequent generation should hereafter be multiplied in the field before testing in the blight chamber. It was ascertained at that time that certain individual plants of *S. bulbocastanum, S. jamesii, S. ajuscoense, S. verrucosun* and *S. antipovichii* were resistant to the prevailing form of the fungus. Good, but not complete, correlation was established between the reaction of the foliage and tubers of a seedling. The tuber tests conducted at this time indicated that the age and size of the samples required to express blight reaction was of paramount importance. At least two dozen tubers seemed necessary to adequately portray infection and in addition, non-suberized tubers from the field were preferable to the stored product. The tuber tests were conducted in large trays housed in the blight chamber. It was further determined that the accuracy of the test was also dependent upon the disposition of the tubers, whether lying on their side or standing on end, and the retention of free moisture about the eye areas. Tubers were found to exhibit varying degrees of susceptibility to the fungus extending from hardly detectable lesions to others where the entire tuber was destroyed. In certain cases, the entire surface of a tuber showed infection extending only a few cells below the periderm.

In 1940 several thousand seedlings whose reactions were between classes 1 to 5 inclusive, were planted in the field but no build-up of the blight organism occurred under the local conditions. A field test and two critical greenhouse tests conducted in 1943 and a further test in 1945, failed to increase the virulance of the blight organism by serial passage through a series of increasingly resistant hosts, (Reddick and Mills, 6). A table published that year revealed that about 35 per cent of the seedlings from resistant plants were unaffected by the common form in the fifth back-cross.

About this time a retest was made of 330 seedlings which had contracted various virus diseases including leafroll, mild mosaic and rugose mosaic. Contrary to the belief upheld by many investigators, these plants showed that there was no increase in susceptibility associated with virus infection. Recently Muller and Munro (4) claimed to have established a quantitative difference between healthy and virus infected plants. Inasmuch as most North American and European potato varieties are carriers of virus diseases the retarding effect mentioned by these authors seems

to have had little effect on the development of blight epidemics under optimal conditions.

In 1943 an isolation station for the propagation of potato seedlings with minimal danger from viral infections was established at Matthew's Point, Albert County. This site was selected because of its coastal exposure, isolation and scarcity of potato aphids in the area. Climatic conditions at this station feature a low summer temperature, a high relative humidity and a strong wind exposure. These features are deemed inimical to aphid multiplication and migration, (Davies, 2). At first it was thought that the relative scarcity of aphids was entirely due to the site but further experiences revealed that in addition the climate favored the development of yearly outbreaks of the blight disease that destroyed the foliage before aphids became abundant.

In 1944 all new seedling productions were first inoculated in the open greenhouse. The inoculum was applied four to eight times after sundown by means of an electrically-operated paint sprayer. During the period of the test, the atmosphere of the greenhouse was maintained in a highly humid condition. Seedlings surviving this preliminary test were further critically tested by the detached leaf method in the blight chamber. In this scheme, leaflets were taken from each plant and tested one, right-side-up and the other up-side-down. Under these conditions blight usually but not always, appeared much earlier and more consistently on the reversed leaves. Since then, the testing of detached leaves has been adopted as the standard method, not only because of its accuracy but because much larger populations can be tested in a given period.

In 1947, two cultures presumed to be biologic forms of the blight organism were obtained from the United States Department of Agriculture as well as about twenty seedlings which were said to function as differential hosts for these cultures. Under our tests, both cultures behaved similarly on the hosts when tested in the chamber during a rainy period but a further test during fine weather, served to differentiate the organisms on these plants.

We have repeatedly observed over a period of years the beneficial effect of testing during rainy periods despite the fact that the atmosphere of the blight chamber was apparently saturated at all times. The ordinary psychrometric instruments have failed to reveal any subtle changes in the atmosphere but apparently environmental differences do exist which are sufficient to enhance or retard the development of the disease.

For many years concordant results were not always obtained when leaves of the same seedling were exposed to blight inoculation. Discordant results were also obtained with leaves of the Green Mountain plant when inoculated six to eight times, first by means of a dropper followed by an atomizer. In other words, some leaves escaped infection under these conditions. It might be well worth recording at this point that outbreaks of blight have never been observed in trays of susceptible foliage adjacent to others containing leaves which were fruiting abundantly. Apparently, the spores were never dispersed from the original site regardless of slight air movements within the chamber caused by the fans of the cooling system.

The claims of Reddick (5) that senescent, chlorotic leaves are prone to infection, have never been substantiated at this laboratory; on the

contrary, green leaves have been consistently found to be more susceptible. It has been possible with the common culture to destroy the foliage of the Sebago variety in the chamber whereas plants of the Green Mountain variety escaped infection. The only noticeable difference between the two varieties was the chlorotic condition of the Green Mountain plants.

There was little evidence until 1949 in either chamber or field, that races of the blight organism existed in the vicinity of Fredericton. It is presumed that until this time only the common form of the organism was present in the field. However, the failure to obtain concordant results with the leaves of the same plant and the occasional breakdown of a seedling heretofore considered resistant, may have been evidence that a new form of the fungus had made its appearance. Possibly these anomalies were due to microclimatic factors rather than a new form.

In the month of September, 1950, 8,507 new seedlings were tested on the greenhouse benches with the common strain of the late blight fungus. After a total of eight inoculations approximately 70.0 per cent of the seedlings had succumbed to the disease. After a further period of two weeks from the last inoculation a few of the plants showed new evidence of blight. Either a new form of *Phytophthora* had appeared in the greenhouse or had gained entrance through a ventilator. All the survivors eventually succumbed to this new form. This was perhaps the first conclusive evidence obtained re the appearance of a new race. Unfortunately, the isolations of the organism made at this time were lost.

In 1951, 10,232 new seedlings were tested in the greenhouse with the common form of blight, and 84.0 per cent succumbed quickly to the disease. Again blight made its appearance amongst the survivors and these slowly went down to a new infection which again apparently developed spontaneously within the greenhouse.

In that year, when plantings of the two new varieties, Keswick and Canso became sufficiently numerous in the Maritime Provinces, they were found to be affected by what appeared to be a new form of the fungus. Fortunately, immunity was never claimed for these varieties because blight was found in a few of the multitudinous tests conducted in the chamber since 1947. These two varieties had heretofore never been found infected in the field, anywhere in Canada, including areas where the common commercial varieties succumbed every year to blight infection. This represents another example of a change in the epidemiology of a disease when its host plant becomes prevalent. The concept that the blight organism is a population persisting at an equilibrium determined by the host range is perhaps the soundest explanation which has been so far advanced to account for this phenomenon. At any rate, it is impossible to register the appearance of a new race unless the differential host is available. It is believed that both aggressive and retrogressive forms of the fungus are regularly isolated by new potato genotypes.

The year 1951 was characterized by the most severe blight epidemic experienced in the Maritime Provinces during the past twenty-five years. Blight made its appearance early in July and by the early part of August, despite repeated attempts to control the disease with fungicides, it became prevalent and destructive on the non-resistant varieties. By the last week of August, many fields were completely destroyed and in most cases, the varieties Keswick and Canso remained unaffected despite the lack of

protection afforded by fungicidal sprays. However, by late August a few fields of these varieties began to show infection in certain localities. In these, the disease seemed to be favored by adjacency to water, shading, *et cetera.*

In early September isolates of the organism were collected on both the Keswick and Canso varieties in the three Maritime Provinces. For this purpose the blight foliage and tubers of the respective varieties were dampened and placed together in a paper bag until blight appeared on the tubers. These were then surface-sterilized and the blight isolated on potato dextrose-agar and grown until the first of April when each respective culture was transferred to detached Green Mountain leaves. Recently it has been found advantageous for apparent reasons to substitute the paper bag with one of polyethylene film.

In 1952 several hundred plants were tested including Aquila, Ashworth, Kennebec, 1256a(23), Essex, 835a(4), Keswick, Cherokee, Canso, Empire, *et cetera,* to determine their value as possible differential hosts. It was found that the various cultures tested reacted erratically at different periods on these hosts and that seedlings alleged by other workers to be of similar genetic constitution as regards blight resistance reacted differently to the isolates. Outstanding in this respect was the variety Aquila which always failed to become infected with any of these isolates. It was further noted that the varieties Keswick and Canso became progressively less susceptible as the tests continued.

In the fall of 1952, 8,301 seedlings were tested with the common strain of the fungus and 33.6 per cent of the plants proved resistant. These survivors were later exposed to a new form of blight which had just previously made its appearance in the field on the Keswick variety, and all proved susceptible. This new form was first noted by a Federal Inspector on a farm in the Mouth of Keswick valley, where the disease was progressively spreading from one corner of the field, shaded by a hedge, adjacent to the barn. It is suspected that the infection developed from a few stored, diseased Keswick tubers which had been disposed of in a cull-pile. Other infections occurred at the Experimental Station some considerable distance from the experimental greenhouses. These infections were found after the Keswick Valley outbreak and in one case the disease was associated with a few rows of the Keswick variety growing adjacent to certain seedlings of similar genetic background and a few commercial varieties. The infection in this plot began adjacent to a hedge and it seemed to arise simultaneously on all varieties within the plot. The other field was a large exposed plot removed about one-quarter of a mile from the latter field. Here the infection was much lighter. The fungus was isolated on rye-meal agar, on which it was maintained for three months, after which it was transferred to and propagated on Green Mountain leaves.

Table 1 gives the details of the reaction of the 1952 isolate and four other isolates made in 1951. These tests were conducted on various differentials including those utilized by workers in England.

This table depicts the reaction of five isolates on these differentials and other hosts when tested under similar conditions with inocula always derived from Green Mountain leaves. Inspection of the table reveals a disparity in the results with any one culture over a period of time. In

TABLE 1.—*The variability in the reaction of different hosts to five isolates of P. infestans.*

	CULTURE SOURCE																								
	Curran P.E.I. 1951					Farm N.B. 1952					Nova Scotia 1951					Lamont P.E.I. 1951					Unknown P.E.I. 1951				
Test No.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Host																									
Canso	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—	—	R	—	—	—	—	—	—	—	—
Keswick	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—	—	R	—	—	—	—	—	—	—	—
834c(29)	—	—	—	—	+	+	+	—	+	+	—	—	—	—	—	—	—	—	—	+	—	—	—	+	+
835a(4)	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
1256a(23)	—	—	—	—	—	—	—	+	—	—	—	—	—	+	+	—	—	+	—	—	—	—	+	+	—
Aquila*	—	R	—	—	—	+	+	—	—	—	—	R	—	—	—	—	R	—	—	—	—	—	—	—	—
1512c(16)*	+	—	—	+	—	—	—	+	+	—	—	—	+	+	—	—	R	+	+	—	+	+	+	+	+
1488b(1)*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28/42*	—	—	—	—	—	—	R	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
120/43*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Orion*	—	—	—	—	+	+	R	+	—	—	—	—	—	—	—	—	R	+	—	—	—	—	—	—	—
38/28*	+	+	+	+	+	—	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Up-to-Date*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	C			C		B		C	C				C	C				C	C		C	C	C	C	C

+ Susceptible — Resistant R Rot *English Differentials

the four old cultures, group C may be determined at times, especially in the "Unknown" culture from Prince Edward Island which seems to be uniform in its reaction on these differentials. The new or "Farm" culture (in these five tests) reacted in such a way as to define group B in one instance, group C in two other trials, and in two tests the reaction was indefinite. It will be noticed that in all cases the Keswick and Canso varieties reacted negatively to all isolates except the "Farm" culture. Furthermore, with the exception of the latter culture the Aquila variety always remained blight-free despite the fact that Black (1) classifies it in his R_1 group that includes Kennebec, 834c(29) and 835a(4), which proved susceptible at various times. Although these plants are all classified as R_1 resisters, the results tabulated are rather confusing from this standpoint. This may be a case of minor gene reaction.

In the spring of 1953 some of Mills' differential hosts were tested with these five cultures. Again the various inocula were always maintained on the Green Mountain variety. Table 2 summarizes the data in regard to these tests. Inspection of the table reveals the possible existence of such forms as A, C, D, CD and BCD, the latter occurring in the "Farm" and "Lamont" cultures. This table also reveals discordant results with the same culture at different periods of testing, and displays the limitation of classifying races of the organism by this scheme.

Table 3 illustrates an attempt to express Black's and Mills' schemes in terms of one another. As can be noted here, no relationship was established with the four old cultures and evidence is presented to show that the "Farm" culture proved lethal to all the genotypes. This might be the form postulated as attacking the host bearing the resistant genes $R_1R_2R_3R_4$. However, this form fails to cause blight in *S. demissum* utilized at Fredericton and it would appear that at least a fifth gene, is active in imparting blight resistance.

Table 4 depicts the reaction of Black's seedlings and the English seedlings to the "Farm" culture which was maintained on the Keswick variety and in addition transferred to and maintained for at least four months on 835a(4), 922-6, 1256a(23) and Pentland Ace. Apparently this so-called "Farm" race is not specific to the Keswick variety as it maintains itself in an apparent unaltered condition for a period of time on these hosts. Attention is directed to the unique behavior of the "Farm" culture as shown in table 1 when maintained on the Green Mountain variety as compared to its behavior when maintained on these selected hosts. Some difficulty was experienced in the early culturing of this strain of the fungus on these varieties, especially 1256a(23) and 922-6. At the present time, this race is well adapted to these hosts. As a matter of interest it may be worthy of note that this form is destructive to the vines of *S. bulbocastanum* var. *glabrum* Correll. On the other hand two plants of *S. bulbocastanum* from Sturgeons Bay, Wisconsin, numbered 22815 have remained unaffected by this form.

On the basis of the evidence presented in this paper, the schemes proposed for the classification of races of *P. infestans* on certain potato genotypes seem inadequate to separate all known variants of the fungus. However, great credit is due to those who have proposed these ingenious schemes. It would appear that the resolution of this problem will require much further work and far greater co-operation amongst investigators.

TABLE 2.—*Reaction of Mills' seedlings to five isolates of P. infestans.*

	CULTURE SOURCE																													
	Curran P.E.I. 1951						Farm N. B. 1952						Nova Scotia 1951						Lamont P.E.I. 1951						Unknown P.E.I. 1951					
Date Inoc.	8	15	15	14	21	21	8	15	15	14	21	21	8	15	15	14	21	21	8	15	15	14	21	21	8	15	15	14	21	21
Date Read	13	19	23	20	24	27	13	19	23	20	24	27	13	19	23	20	24	27	13	19	23	20	24	27	13	19	23	20	24	27
Host																														
3WM—13	—	—	—	+	—	—	+	+	+	+	+	+	—	+	—	+	—	—	—	—	+	+	—	—	—	—	—	—	—	—
Essex	—	—	+	+	—	+	+	+	+	+	+	+	—	—	—	—	—	—	—	—	+	+	+	+	+	—	—	+	+	+
3WM—19	—	—	—	—	—	—	+	—	+	+	+	+	—	—	+	—	—	—	—	—	—	+	—	+	—	—	—	—	—	—
3XE—1	—	—	—	+	—	—	+	—	+	+	+	+	—	—	—	—	—	+	—	—	—	+	+	+	—	—	—	+	—	—
3AB—2	+	—	+	+	+	+	+	—	+	+	+	+	—	+	+	+	+	+	+	—	+	+	—	+	+	+	+	+	+	+
Keswick		—	—	—	—	+		+	+	+	+	+		—	—	+	—	—		—	—	+	—	+		—	—	+	—	+
Canso		—	—	—	—	+		+	+	+	+	+				+	—	—		—	—	+	—	+		—	—	+	—	+
Form	C				C		BCD	D	BCD	BCD	BCD	BCD					C		C			BCD				C	C	CD		
Temperature Fahrenheit	69	69	69	58	65	65	69	69	69	58	65	65	69	69	69	58	65	65	69	69	69	58	65	65	69	69	69	58	65	65

\+ Susceptible — Resistant

TABLE 3.—*The reaction of Black's and Mills' differentials to five isolates of P. infestans.*

		CULTURE SOURCE														
		Curran P.E.I. 1951			Farm N. B. 1952			Nova Scotia 1951			Lamont P.E.I. 1951			Unknown P.E.I. 1951		
Date Inoc.		14	21	21	14	21	21	14	21	21	14	21	21	14	21	21
Date Read		20	24	27	20	24	27	20	24	27	20	24	27	20	24	27
Host	Genotype															
835a(4)	R_1	—	—	+	+	+	+	—	—	+	+	+	+	+	—	+
1512c(16)	R_2	—	—	—	+	+	+	—	—	—	—	—	—	—	—	—
1253a(12)	R_3	—	—	—	+	+	+	—	—	+	+	—	+	+	—	+
1563c(14)	R_4	+	—	—	+	+	+	—	—	—	+	—	+	—	—	+
1647b(1)	R_1R_2	+	—	+	+	+	+	+	—	—	+	+	+	+	—	+
1661b(7)	R_1R_3	—	—	+	+	+	+	—	—	+	+	—	+	—	—	+
1506b(9)	R_1R_4	—	—	—	+	—	+	—	—	—	—	—	+	—	—	—
1682c(1)	R_2R_3	—	—	+	+	—	+	—	—	+	—	—	—	—	—	—
2070ab(31)	R_2R_4	+	—	+	+	+	+	—	—	+	+	—	+	—	—	+
1584c(10)	R_3R_4	—	—	+	+	—	+	—	—	+	—	—	+	—	—	—
3WM—13	BcD	+	—	—	+	+	+	+	—	—	+	—	—	—	—	—
Essex	bcD	+	—	+	+	+	+	—	—	—	+	+	+	+	+	+
3WM—19	Bcd	—	—	—	+	+	+	—	—	—	+	—	+	—	—	R
3XE—1	bCD	+	—	R	+	+	+	—	—	+	+	—	+	+	—	—
3ab—2	bCd	+	+	+	+	+	+	+	+	+	+	—	+	+	+	+
Keswick	....	—	—	+	+	+	+	+	—	—	+	—	+	+	—	+
Canso	....	—	—	+	+	+	+	+	—	—	+	—	+	+	—	+

+ Susceptible — Resistant R Rot

TABLE 4.—*The reaction of Black's and English differentials to five isolates of P. infestans.*

	CULTURE SOURCE								
	Farm N. B. 1952		1256a-23	835a-4		Pentland Ace		922-6	
Date Inoc.	18		18	18		18		18	
Date Read	24		24	24		24		24	
Host									
835a(4)	+		+	+		+		+	
1512c(16)	+		+	+		+		+	
1253a(12)	+		+	+		+		+	
1563c(14)	+		+	+		+		+	
1647b(1)	+		+	+		+		+	
1661b(7)	+		+	+		+		+	
1506b(9)	+		+	+		+		+	
1682c(1)	+		+	+		+		+	
2070ab(31)	+		+	+		+		+	
1584c(10)	+		+	+		+		+	
Date Inoc.	26	26	26	26	26	26	26	26	26
Date Read	30	4	30	30	4	30	4	30	4
Host									
28/42	—	+	+	+		+		—	+
120/43	+		+	+		+		+	
Orion	+		+	+		+		+	
38/28	+		+	+		+		+	
1488b (1)	—	+	+	—	+	—	+	—	+
1512c (16)	+		+	+		+		+	
King Edward	+		+	+		+		+	
Up-to-date	+		+	+		+		+	

\+ Susceptible — Resistant

Evidence points to the fact that standard conditions of testing must be defined and maintained by all workers. The time also seems to have arrived for exploring the potential value of species other than *S. demissum* in breeding for blight resistance.

Most of the data contained in this report have been taken from unpublished Annual Reports of the Dominion Laboratory of Botany and Plant Pathology, Fredericton, New Brunswick, to the Dominion Botanist, Ottawa.

Finally the authors wish to extend their thanks to the many individuals in Great Britain, the United States and Canada who have contributed in any way towards the preparation of this paper.

Summary

A resume is presented of the testing for late blight resistance conducted at Fredericton, New Brunswick, Canada during the past twenty years. The account is mainly concerned with the testing of *S. demissum* x *S. tuberosum* hybrids.

Prior to 1949 there was little evidence for the existence of specialized races of *P. infestans* and it is assumed that only the so-called common form of the fungus was prevalent in the field. In 1951 two seedlings, Keswick and Canso, hitherto considered resistant, blighted in the field. These varieties blighted again in 1952.

Isolates of the fungus from these two varieties behaved erratically in many cases when tested on a series of differential hosts obtained from Great Britain and the United States. Moreover, one of these isolates caused infection on all the differential hosts employed.

Existing schemes which have been proposed for the differentiation of the races of this organism have been proven to be inadequate. Evidence has been presented indicating that blight resistance is governed by the action of more genes than those already postulated.

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FURTHER STUDIES CONCERNING THE INFLUENCE OF IRRIGATION ON THE NITROGEN, PHOSPHORUS AND POTASH REQUIREMENTS OF SIX POTATO VARIETIES[1]

J. HOWARD ELLISON[2] AND WALTER C. JACOB[3]

This report gives four years' results with six potato varieties which were grown on the permanent fertility plots at the Long Island Vegetable Research Farm. Jacob, White-Stevens and Wessels (3), reporting on three years' results from the same fertility plots, indicated that the previous levels of N, P and K should be changed in future investigations. The response to nitrogen indicated that the levels of N were too low (40, 80 and 120 pounds/A), and the lack of response to phosphorus indicated that the levels of P were too high (80, 160 and 240 pounds P_2O_5/A). Therefore, in 1949 the levels of N, P_2O_5 and K_2O were all adjusted to 60, 120 and 180 pounds per acre, and were so maintained through 1952 when the present study was concluded.

MATERIAL AND METHODS

Nitrogen, phosphorus (P_2O_5) and potash (K_2O) were each used at 60, 120 and 180 pounds per acre in all combinations, making 27 fertilizer treatments. A blanket application of water soluble magnesium of 100 pounds of MgO per acre was used each year, and all fertilizer was applied in bands at planting time. The fertilizer plots consisted of four 34 inch rows 28 feet long, and yields were taken on the inner 24 feet of the two middle rows.

Three varieties were tested each year in factorial combinations with the 27 fertilizer treatments, and the two blocks were arranged so that one-half of each block could be irrigated and the other half not. Jacob (1) gave details concerning the experimental design and statistical analysis used in the present study.

Overhead irrigation was applied at approximately one inch per week minus rainfall. For a summary of the weekly rainfall and the irrigation applied see table 1.

Green Mountain, Katahdin and Cobbler varieties were grown in 1949 and 1950, and the data were combined into one analysis in order to study the influence of years on the varieties and other factors. In 1951 and 1952 the plots were planted to Essex, Pontiac and Kennebec, so that the influence of years again could be determined. Fortunately each pair of years consisted of one "dry" and one "wet" year (see table 1), thus affording a good chance to study the variety-fertilizer-irrigation treatments under diverse growing seasons. Although the total rainfall fails to show

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TABLE 1.—*Inches of rain and irrigation by weeks from planting to maturity of potatoes.*

Weeks after Planting	1949		1950		1951		1952	
	Rain	Irrig.	Rain	Irrig.	Rain	Irrig.	Rain	Irrig.
1	1.31		.60		.31		T*	
2	.97		.46		1.06		.86	
3	.49		1.04		.19		.99	
4	T		.62		.94		1.66	
5	1.24		.21		.15	.80	.53	
6	.40		1.72		.99		1.81	
7	0.00	1.00	2.06		.51	.50	1.79	
8	.03	1.00	1.67		1.10		2.09	
9	.00	1.00	.39		.84		.28	
10	.00	1.00	.36	1.25	.35	.65	.35	.65
11	T	1.00	.43	.60	.88		.49	.50
12	.00	.90	.08	.70	.04	1.10	T	1.00
13	.73		.68	.30	.00	1.00	.00	1.00
14	1.07		1.81		.45		.79	
15	1.34		.79		.97	.60	T	1.00
16	2.02		.24	.80	.12	.90	.57	
17	.13		2.07		.13		1.95	
18	1.35		.02	1.00	2.53		3.25	
19	......		1.04		......		.91	
20	......		.05		......		1.73	
Total	11.08	5.90	16.33	4.65	11.56	5.55	20.05	4.15
Weekly Mean	0.62	0.95	0.82	0.78	0.64	0.79	1.00	0.83

*T = Trace

that 1949 and 1952 were drought years, a careful examination of table 1 reveals that the distribution of rainfall was poor in 1949 and 1952, being critical in June and July. This, coupled with the higher than average temperatures during the same months, was responsible for a marked response to irrigation in 1949 and 1952 compared with 1950 and 1951. June and July mean maximum temperatures for 1949, 1950, 1951 and 1952 were respectively 84°, 80°, 80° and 84° F.

In 1949 the potatoes were planted on April 15, 18 and 21 and the vines were killed with sodium arsenite on August 24 and 26. These and all other cultural operations were handled by replications, in order to

avoid, as much as possible, any biased effect on the treatments. The 1950 planting took place on April 10 and 11, and the vines were killed on August 26. The Essex, Pontiac and Kennebec were planted on April 11 and 12, 1951 and were killed on August 21. Potatoes were planted on April 3 and 4 in 1952 and the vines were killed on August 25.

1949 and 1950 Experiments: Yield results from 1949 and 1950 were combined into one analysis in order to study the influence of years on the effects of the other factors. Those results which do not involve interactions with years are presented as averages of the two years. In cases involving significant interactions with years, the data are presented graphically, showing the individual annual results. Differences referred to in this paper are significant at odds of 19:1 or greater.

Although the variances for irrigation and for years are significantly greater than the error terms, neither was significantly different from the irrigation x years interaction and is not presented separately. The highly significant interaction of irrigation x years is presented graphically in figure 1. During the hot, dry season of 1949, the response to irrigation resulted in an increase of 206 bushels per acre (mean of all varieties and fertilizer treatments). The growing season in 1950 was more favorable, and the response to irrigation was small, being only ten bushels per acre.

Varieties differed significantly, Katahdin and Green Mountain yielding more than Cobbler, but not differing from each other as seen in table 2.

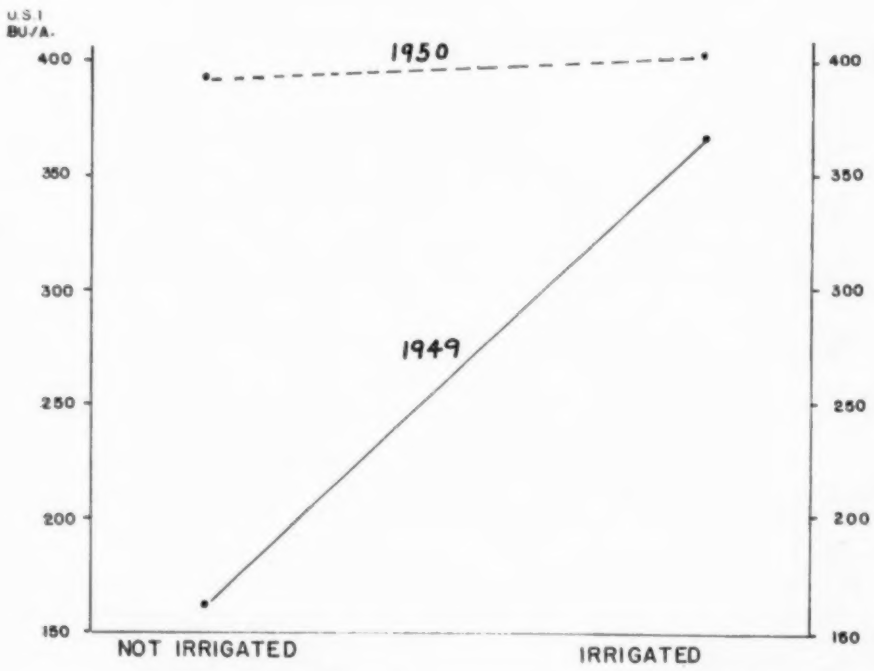

FIGURE 1.—Influence of years on the response of potatoes to irrigation.

TABLE 2.—*Yield of Katahdin, Green Mountain and Cobbler potatoes (Mean of all irrigation and fertilizer treatments for 1949 and 1950).*

Variety	U.S. 1 Bus./A
Katahdin	341
Green Mountain	343
Cobbler	309
L.S.D. @ .05	27

The variance for nitrogen was large, and though significantly greater than the error, was not significantly different from the nitrogen x years interaction. This interaction is presented in figure 2. There was a response to nitrogen each year, but the response was greater in 1950 than in 1949, especially to high nitrogen.

Phosphorus and potash were significant compared to the error term, but not when compared to interactions involving P and K, so will not be discussed as main effects. Significant interactions involving P and K are presented.

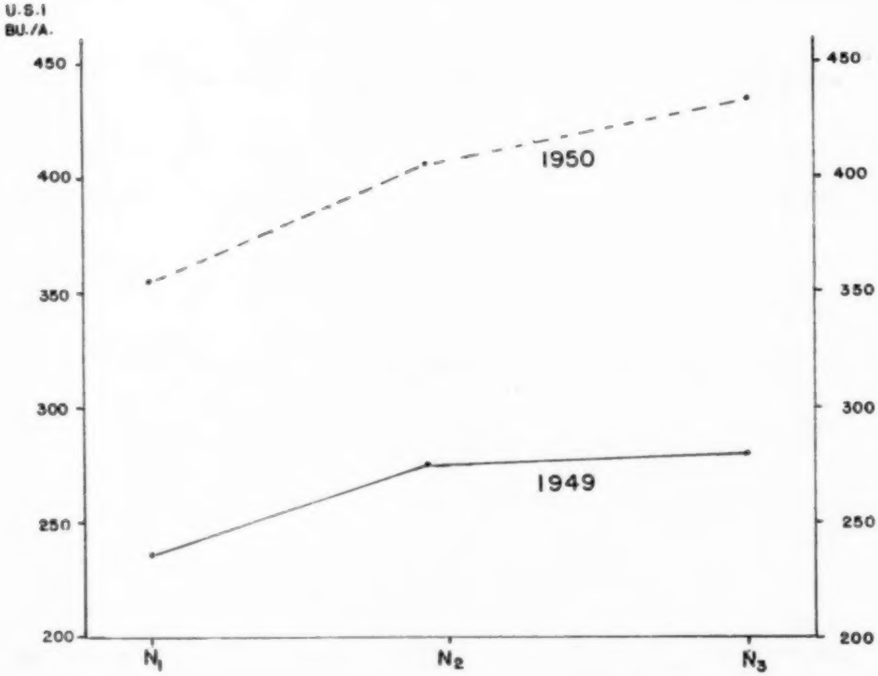

FIGURE 2.—Influence of years on the response of potatoes to nitrogen.

Varieties responded differently to various levels of phosphorus as shown in figure 3. Green Mountain responded the same to 60 and 120 pounds P_2O_5, and was reduced in yield by 180 pounds. Katahdin responded more to 120 pounds P_2O_5 compared with 60 pounds, but 180 pounds produced the same as 120. Cobbler responded most favorably to the high phosphorus level.

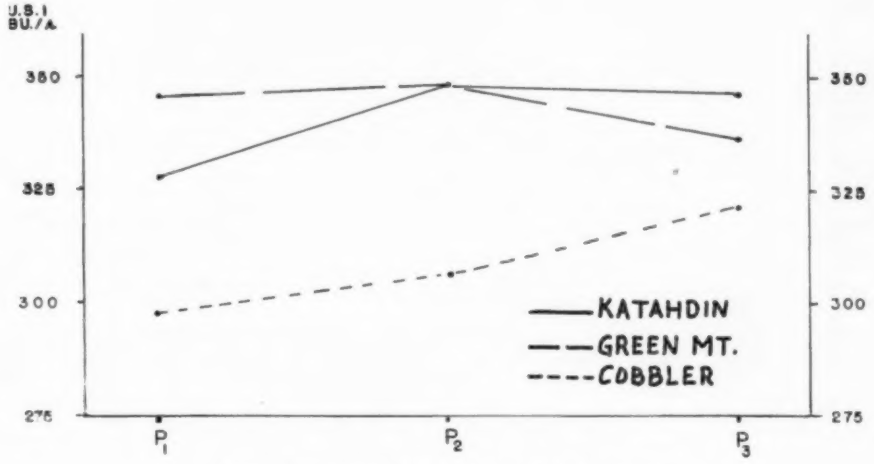

FIGURE 3.—Response of varieties to phosphorus.

Potassium influenced the response of varieties to nitrogen. At low potash Green Mountain and Katahdin responded more than Cobbler to medium nitrogen, and Katahdin responded well to high nitrogen. Cobbler increased moderately with high nitrogen, but Green Mountain failed to respond as revealed in figure 4. At medium potash all three varieties responded well to medium nitrogen but not to high nitrogen. At high potash Katahdin responded greatly to medium nitrogen and slightly less to high nitrogen, whereas Cobbler increased sharply with each increase in nitrogen, and Green Mountain showed only a moderate gain with each nitrogen increment.

Irrigation greatly influenced the response of varieties to nitrogen as shown in figure 5. With irrigation, Katahdin and Cobbler responded markedly to medium *versus* low nitrogen, and responded moderately to high nitrogen, whereas Green Mountain responded only moderately to medium nitrogen and yielded no more with high nitrogen. Without irrigation, Katahdin and Green Mountain responded well to medium nitrogen and only slightly to high nitrogen. Cobbler, on the other hand, responded only slightly to medium nitrogen and showed a greater increase with high nitrogen.

1951 and 1952 Experiments: In 1951 and 1952 Essex, Pontiac and Kennebec were grown on the same permanent fertility plots which were used during the previous two years. The 1951 and 1952 experiments were combined into one statistical analysis in order to study the effects of years, as was done with the 1949 and 1950 results.

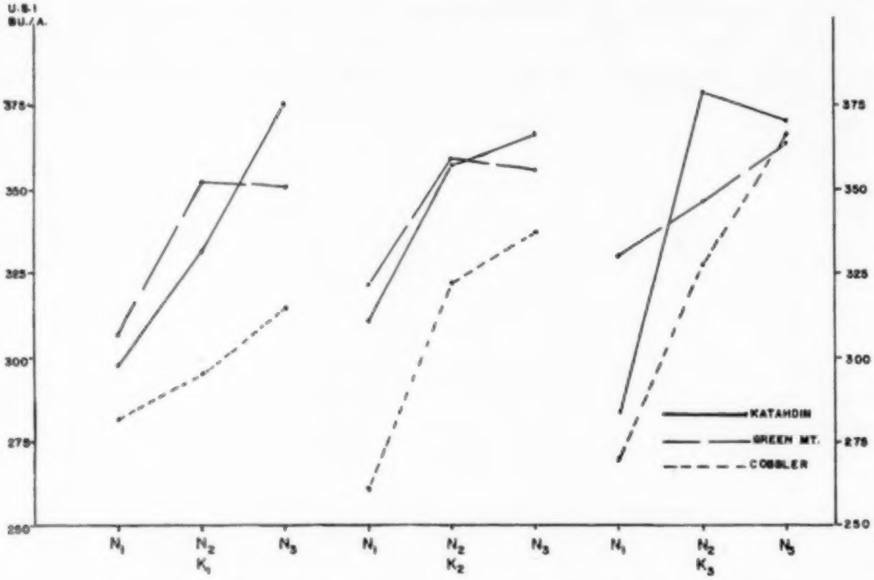

FIGURE 4.—Influence of potash on the response of varieties to nitrogen.

The average irrigation effect of 1951 and 1952 was highly significant even when compared to the highly significant interaction of nitrogen x irrigation x years. The yield increase due to irrigation was 102 bushels per acre, when yields of all varieties and fertilizer treatments were averaged (table 3).

TABLE 3.—*Effect of irrigation on the yield of potatoes (Mean of all treatments in 1951 and 1952).*

	U.S. 1 Bus./A
Irrigation	383
No Irrigation	281

Variety yields differed very significantly, with Essex producing the largest yield, Pontiac being intermediate with Kennebec yielding the least, as shown in table 4.

Nitrogen produced a highly significant yield increase when the rate was raised from 60 to 120 pounds of N per acre, and just missed significant when the rate was raised from 120 to 180 pounds of N per acre as shown in table 5.

The response to nitrogen and irrigation differed in 1951 as compared with 1952. The highly significant interaction of nitrogen x irrigation x years is presented graphically in figure 6. Most of the variance in this

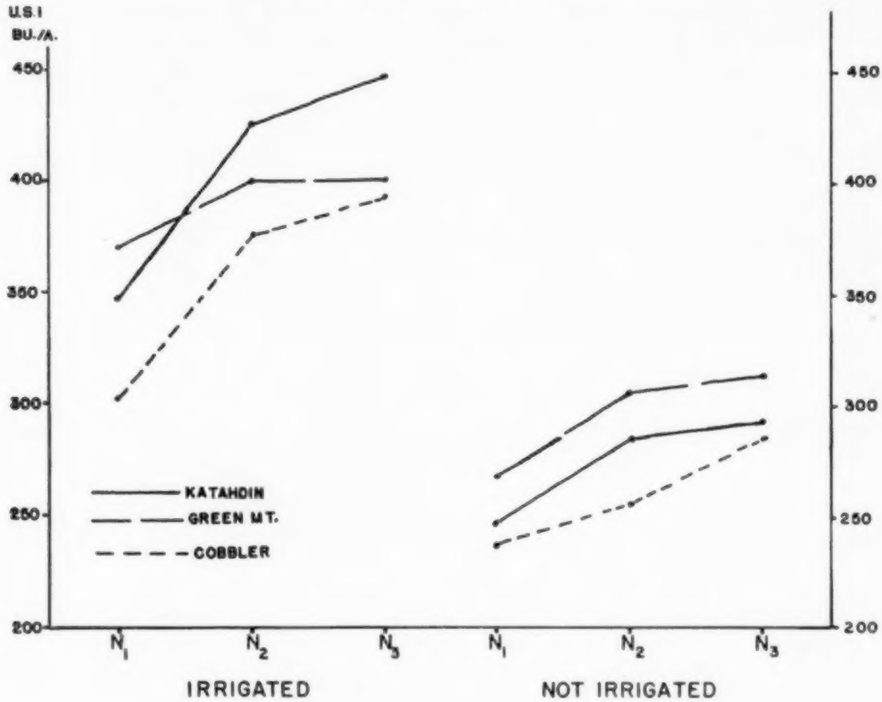

FIGURE 5.—Influence of irrigation on the response of varieties to nitrogen.

TABLE 4.—*Yield of potato varieties (Mean of all treatments in 1951 and 1952).*

Varieties	U.S. 1 Bus./A
Essex	364
Pontiac	336
Kennebec	297
L.S.D. @ .05	18
@ .01	30

interaction is associated with the very large response to irrigation in 1952 compared to the moderate response in 1951. With irrigation the largest response to nitrogen occurred between 60 and 120 pounds of N per acre, especially in 1952, and there was a moderate response each year to 180 pounds of N. Without irigation there was moderate response to medium nitrogen but no further increase caused by high nitrogen.

TABLE 5.—*Effect of nitrogen on the yield of potatoes.*
(Mean of all varieties and fertilizers in 1951 and 1952).

	U.S. 1 Bus./A
60 lbs. N per acre	287
120 lbs. N per acre	348
180 lbs. N per acre	363
L.S.D. @ .05	18
@ .01	30

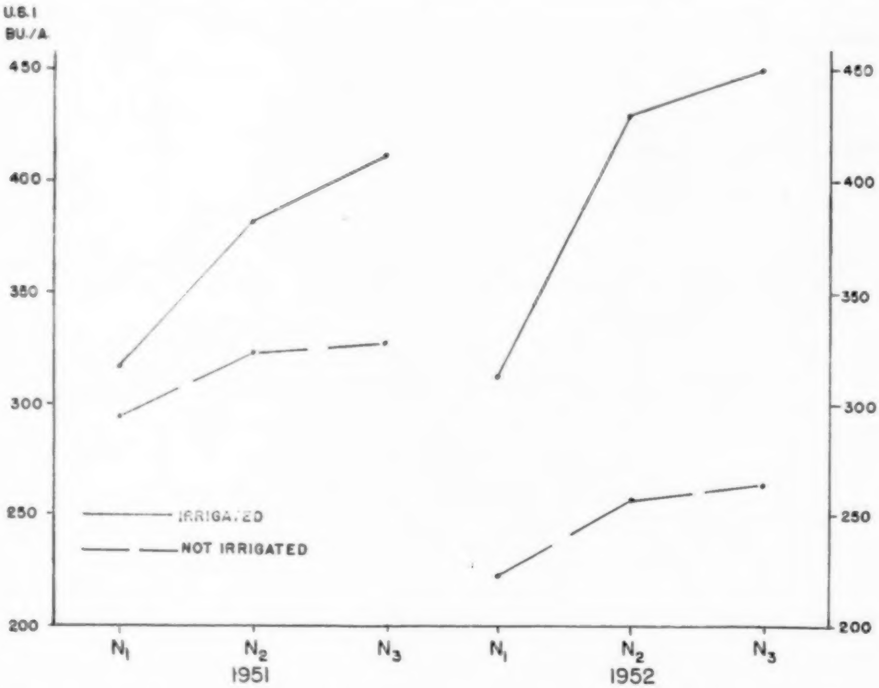

FIGURE 6.—Influence of irrigation on the response to nitrogen during two growing seasons.

Neither phosphorus nor potash produced a significant main effect, but phosphorus greatly influenced the response of varieties to nitrogen. The nitrogen x phosphorus x variety interaction is preesnted in figure 7. Kennebec was more affected by phosphorus than were the other two varieties. At low phosphorus, Kennebec produced a linear response to nitrogen, at medium phosphorus it produced a large response to medium nitrogen, and decreased slightly at high nitrogen. With high phosphorus Kennebec increased moderately with medium nitrogen and decreased moderately with high nitrogen. Essex and Pontiac produced fair to good

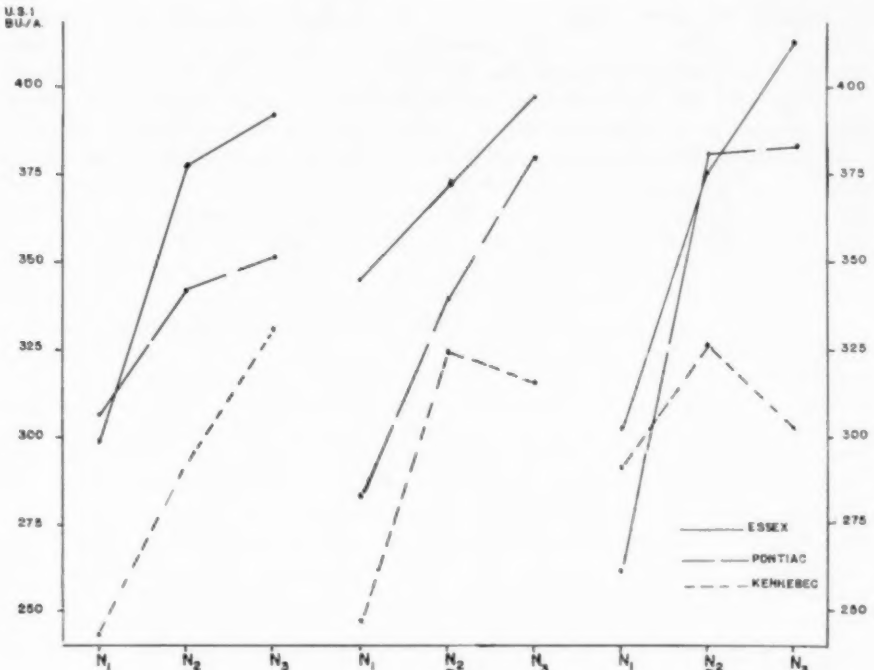

FIGURE 7.—Influence of phosphorus on the response of varieties to nitrogen.

yield increases with all nitrogen increments and at all phosphorus levels with one exception. At high phosphorus Pontiac failed to respond more to high nitrogen than to medium.

DISCUSSION

The large response (mean of Katahdin, Green Mountain and Cobbler) to irrigation in 1949 was due to the severe drought, with water being the limiting factor on the unirrigated plots. The same experiment showed little difference due to irrigation in 1950, because of well distributed rainfall during that season, as seen in figure 1. The larger response to nitrogen in 1950 compared with 1949 was apparently due to the more favorable growing conditions in 1950 as noted in figure 2. In 1951 and 1952 (mean of Essex, Pontiac and Kennebec) the response to nitrogen was greater with irrigation than without, showing that adequate moisture must be maintained in order for the plants to utilize large amounts of nitrogen, as shown in figure 6. The irrigation effect was more pronounced in 1952 than in 1951 since the 1952 season was drier.

Varieties differed in their response to certain fertilizer treatments. Green Mountain failed to respond to high nitrogen, even with irrigation, and therefore should not be fertilized as heavily as Katahdin or Cobbler. These results are presented in figure 5. The same conclusion can be drawn

in regard to phosphorus. Figure 3 shows that Katahdin and Cobbler responded slightly, but Green Mountain was depressed in yield by high phosphorus. At high phosphorus Kennebec was reduced in yield by high nitrogen, and Pontiac failed to respond to high nitrogen. That Essex however, responded to high nitrogen at high phosphorus is indicated in figure 7.

Jacob, White-Stevens and Wessels (3) reported little response of potatoes to phosphorus on Long Island, and Jacob, *et al* (2) showed by tracer technique that very little of the fertilizer phosphorus is absorbed by potatoes grown on soils rich in P_20_5. The soil used for these experiments is typical of most of the potato soils on Long Island, which are rich in P_2O_5, due to continuous heavy fertilization.

On the basis of the results of the present study in addition to the evidence given above, a new fertilizer recommendation was made, changing the ratio from 1-2-1 to 1-1-1. A 7-7-7 analysis was deemed better than a 10-10-10, because of the high residual acidity and poorer physical condition of the latter. The recommended rates of fertilizer supply 125 to 140 pounds each of N, P_2O_5 and K_2O per acre. Lighter soils and all irrigated soils should receive the larger amount. Although certain varieties differ in their response to different fertilizer ratios, most of the necessary adjustments can be made by regulating the rate of application of the 1-1-1 ratio, since nitrogen is by far the most important element involved. For instance, Green Mountain should receive only 125 pounds each of N, P_2O_5 and K_2O; Cobbler, Katahdin, Pontiac and Kennebec should receive 140 pounds, and Essex should receive 160 to 170 pounds. There is evidence from unpublished data to indicate that with irrigation, Cobbler and Katahdin benefit from nitrogen side dressings of 30 to 60 pounds of N, especially when heavy spring rains leach nitrogen applied at planting time. This may apply to other varieties also.

Although it is known that phosphorus ties up soluble aluminum in acid soils, there is no evidence from these experiments that aluminum toxicity will develop from the use of 1-1-1 rather than 1-2-1 ratio on heavily fertilized Long Island soils. No reduction in yield is associated with plots which have been fertilized with only 60 to 80 pounds of P_2O_5 per acre for seven consecutive years, and the recommended rate is 125 to 140 pounds of P_2O_5.

Soil samples were taken in the fall of 1952 in order to study the cumulative effects of the fertilizer treatments, and to correlate the soil test results with yield results. A separate paper, dealing with this phase of the study, will be published at a later date.

Summary

Permanent fertility plots, involving three levels each of N, P and K, in factorial arrangement with and without irrigation, were used to study the fertilizer requirements of six potato varieties. Four years' results are reported. The soil is a Sassafras fine sandy loam, which is rich in phosphorus and potash, due to many years of heavy fertilization prior to being set up as a fertilizer experiment.

Large yield increases were associated with nitrogen additions, but

little response to phosphorus or potash was noted. High nitrogen was more effective with irrigation than without.

Although certain varieties responded best to different fertilizer ratios, most of the varieties can be efficiently fertilized by regulating the rate of application of a 1-1-1 ratio. This rate should be governed to supply the proper amount of nitrogen, since it is by far the most important element involved.

Green Mountain should receive only 125 pounds each per acre of N, P_2O_5 and K_2O; Cobbler, Katahdin, Pontiac and Kennebec should receive 140 pounds, and Essex should receive 160 to 170 pounds. The fertilizer rate should be adjusted somewhat to meet the particular soil conditions and irrigation practice involved on individual farms.

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POTATO NEWS AND REVIEWS

COMBINATION POTATO GRADER-POLISHER[1]

Carl W. Hall[2]

When potatoes are graded out of storage, there is little room for the grading equipment because of the cramped conditions in the storage. A portable combination grader-polisher was designed and constructed from available commercial parts. The unit was designed to provide a clean and sized product to the consumer and permit the potato grower to carry out these operations with one piece of equipment. Thus, less space would be required with one piece of equipment, and at a lower cost. To improve the sorting efficiency, red, yellow, and daylight fluorescent tubes and incandescent lights were tested over the sorting table.

The conventional processing equipment consists of (1) an elevator-conveyor into which the potatoes are dumped, (2) a polisher or cleaner, if used, consisting of cloth buffers, (3) a grader in which the small potatoes are removed, and (4) a sorting table on which the undesirable potatoes are manually removed. The two units, the grader and polisher, were combined as shown in figure 1, to eliminate five feet of space normally occupied by the polisher.

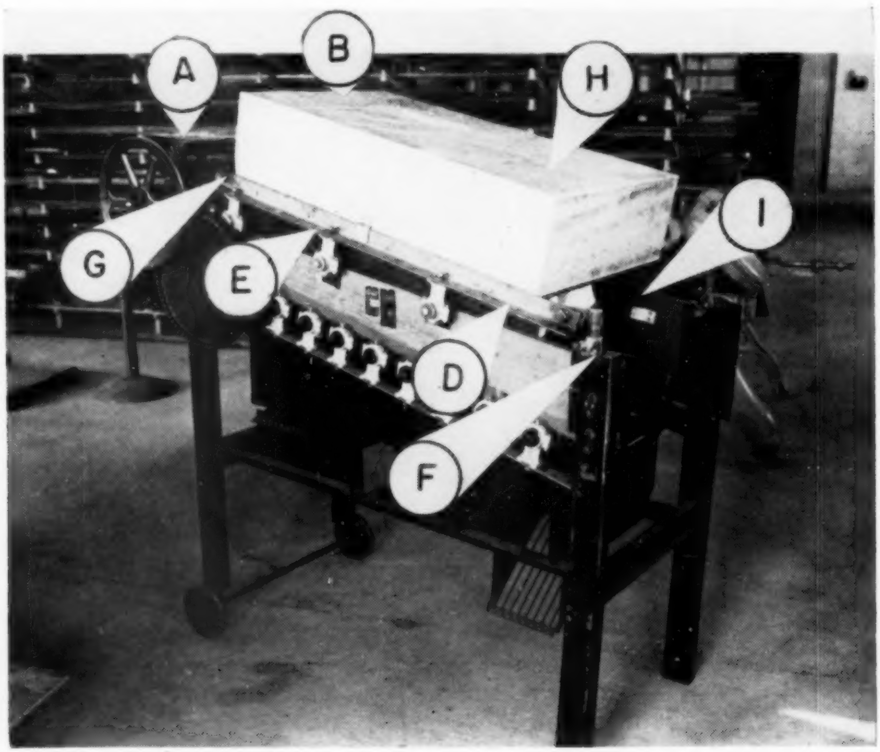

Figure 1.—Combination Grader-Polisher

The easiest way to combine these two units consists of mounting the polisher mechanism above the grader, using the conventional frame of the grader to support both mechanisms. The following factors were considered when building the combination unit.

1. Two motors were used to drive the unit—one for the grader, elevator, and sorting table, and one for the polishing rolls, of ½ and ¾ Hp, respectively. The maximum starting current on the electric line, which is a critical factor in many of the small storages in Michigan, will be lower when two small motors are started separately in comparison to the starting current of one large motor. The drive mechanism is simplified with two motors (A and B).
2. Three polishing rolls (C) were placed above and between the grader rolls, and mounted on an angle iron frame (D). Slots (E) were provided in the angle iron for changing the spacing between rolls. (Figure 2.)
3. The polishing rolls were adjustable in height by a shaft supported in a pipe with a set screw (F), through a range of 6½ to 10 inches from the center line of the grader rolls to the center of the polisher rolls. A slotted hole was used at the other end (G) for adjustment. These adjustments permit moving the polishing unit down as wear occurs on the polishing cloths.

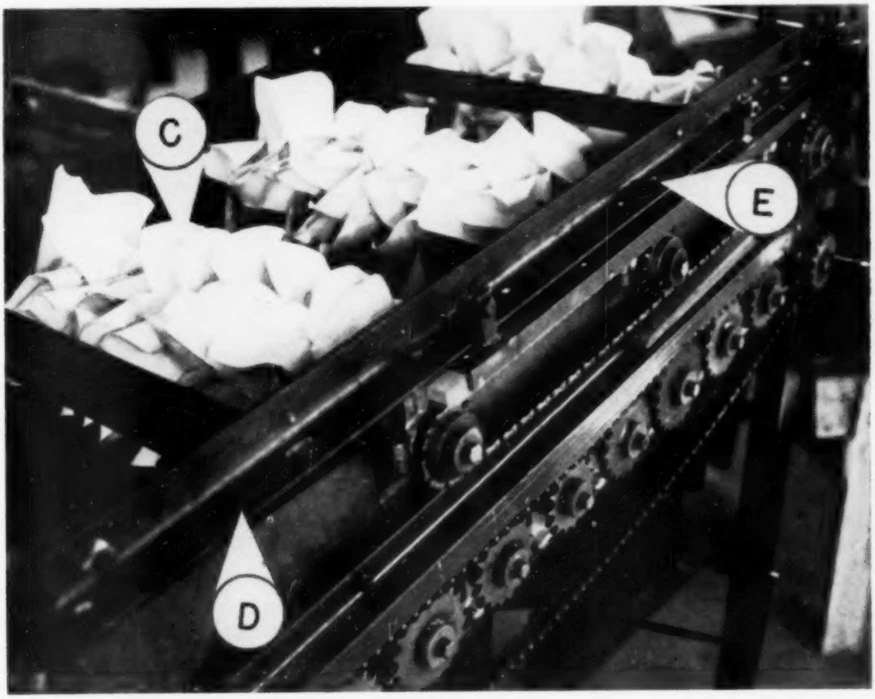

FIGURE 2.—Driving mechanism of grader and polisher rolls (the metal cover over the unit has been removed to show the polisher unit).

4. The top polishing unit was placed on hinges in a slotted hole at the upper end (G) so that the unit could be readily moved to permit one to get to the rubber grading spools for maintenance and service.
5. The polishing rolls (C) with cloth buffers were run about 400 rpm. The direction of rotation of the polishing rolls is such as to help push the potatoes through the unit. The rubber spool grader rolls were designed to operate at 65 rpm.
6. The cover was constructed of galvanized tin (H), and leather belting (I) was used along the sides between the cover and grader.

Results

The unit constructed as illustrated and described worked satisfactorily for cleaning potatoes grown in Emmet sandy loam soil. One of the commercial growers in the Emmet County area duplicated the unit for his own use before the season was completed. He was satisfied with the operation of his unit. The cost of the combination unit is approximately $300.00 less than the sum of the two individual units.

Fluorescent lights in yellow, red, or daylight tubes, used individually or in combination, were not satisfactory for grading potatoes because of the difficulty in seeing greened potatoes. The incandescent light was entirely satisfactory.

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This paper was prepared expressly for the American Potato Journal and is approved for publication by the Michigan Agricultural Experiment Station as Article 1550.
[2]Department of Agricultural Engineering, Michigan State College.
[3]Acknowledgment is given to the Emmet County Growers' Cooperative, Inc., Petoskey, Michigan, for financing construction of the unit and testing it. Also to R. L. Maddex, E. J. Wheeler and R. S. Lincoln for their help in the construction and demonstration of the unit. The John Bean Mfg. Company cooperated in the design of the unit.

ROOT FASCIATION IN THE IRISH POTATO *(SOLANUM TUBEROSUM)*[1]

C. E. Rosenquist[2]

Fasciation of any kind is rare, although in potatoes it is probably more prevalent than usually thought. Fasciated stems and leaves are very difficult to identify in a field and frequently go unnoticed, especially when fasciation involves only a small portion of a branch, and when only two stems are grown together.

While observing potted potato plants of the varieties Red Triumph, Progress and Red Warba, which had two-stem or multiple-stem fasciations, the question of the occurrence of root fasciation arose. If root fasciations appeared at all it was thought that they would appear on plants showing stem, tuber and sometimes leaf fasciations.

Consequently the root systems of the 35 available plants, which showed stem and other fasciations, were subjected to a careful scrutiny. Each of three of these plants had a single pair of roots grown together along a length of approximately four inches. In figure 1 is shown a fasciated root which is typical of all those found to date.

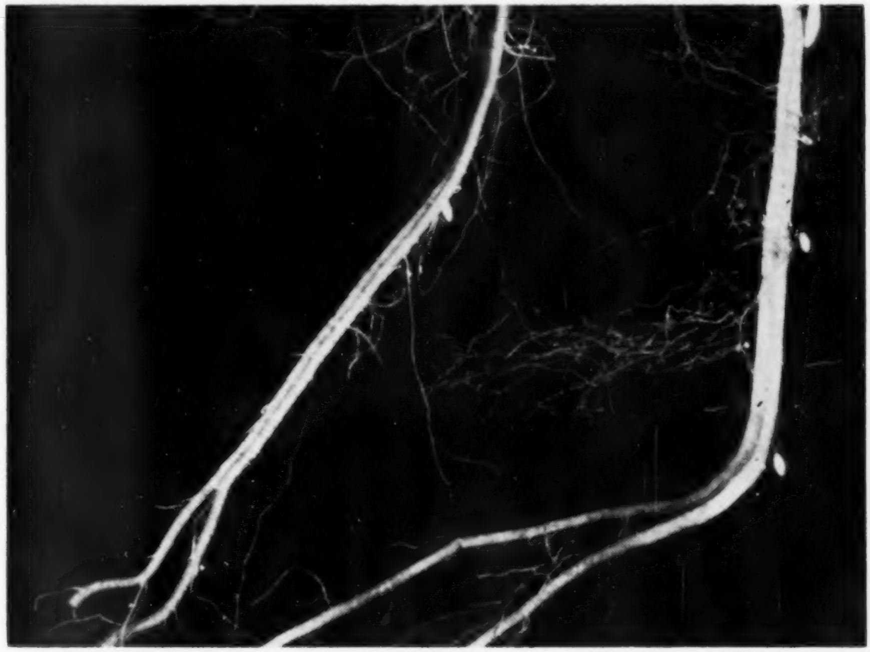

FIGURE 1.—Typical fasciated roots of Irish potato.

The root systems of 194 additional potted potato plants of the same three varieties were later examined closely for fasciated roots. Seven of these plants had fasciated stems but no fasciated roots. The remaining 187 plants had no stem or leaf fasciations but each of three of them had a single pair of fasciated roots three to six inches long. One of these plants with fasciated roots originated from a fasciated plant. If this plant were included in the fasciated-stem group the totals would become 4 fasciated root types among 43 fasciated plants and only 2 among 186 non-fasciated plants.

SUMMARY

The root systems of 175 Triumph, 50 Progress and 4 Red Warba potato plants were carefully scrutinized in order to detect root fasciation. Only 6 plants showed root fasciations and all of these were of the double type, involving only two roots. Forty-two plants with fasciated stems produced a single example of fasciated roots on each of three plants. Of the 187 non-fasciated plants only three showed fasciated roots and one of these could be traced back a generation to a fasciated parent plant.

The above observations indicate that root fasciation in potato plants may be as common as stem fasciation and that fasciated roots are considerably more prevalent among plants having fasciated, than among those having non-fasciated stems.

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